United States Patent [19]

Shoemaker

[11] **Patent Number: 4,783,630**

[45] **Date of Patent: Nov. 8, 1988**

[54] **METAL DETECTOR WITH CIRCUITS FOR AUTOMATICALLY SCREENING OUT THE EFFECTS OF OFFSET AND MINERALIZED GROUND**

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[73] Assignee: **White's Electronics, Inc.**, Sweet Home, Oreg.

[21] Appl. No.: **844,797**

[22] Filed: **Mar. 27, 1986**

[51] **Int. Cl.**[4] **G01V 3/11**; G01R 33/00

[52] **U.S. Cl.** **324/329**; 324/233

[58] **Field of Search** 324/326-329, 324/233

[56] **References Cited**

U.S. PATENT DOCUMENTS

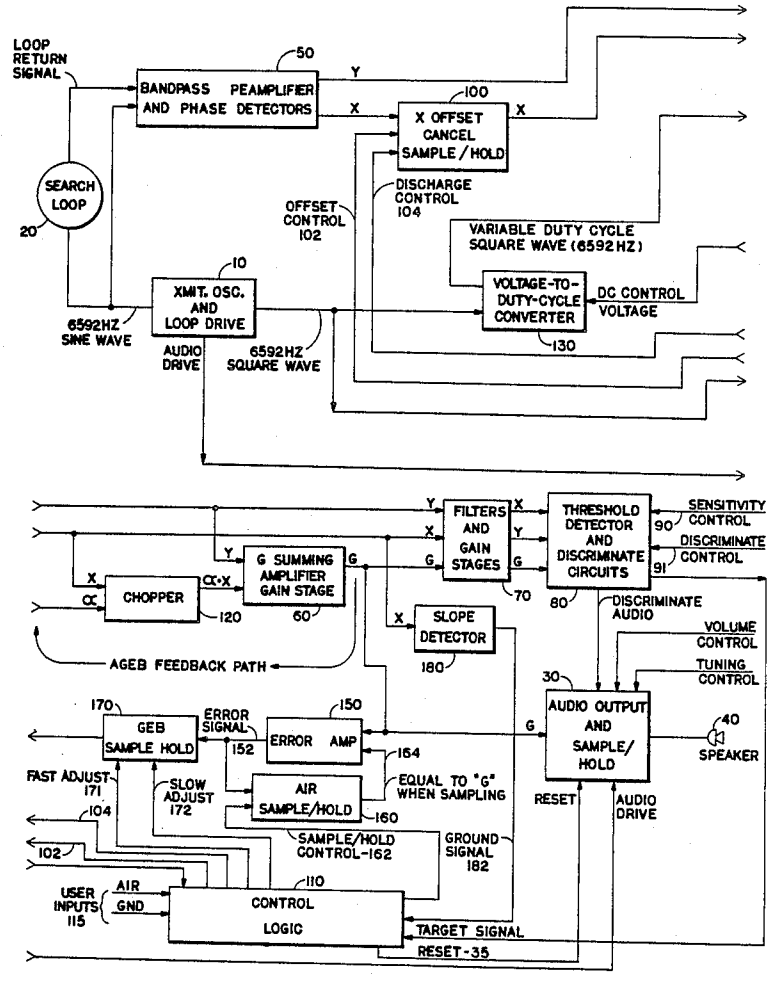
4,303,897	12/1981	Podhrasky	324/324
4,387,338	6/1983	Hecht et al.	324/236
4,470,015	9/1984	Hirschi et al.	324/233

Primary Examiner—Reinhard J. Eisenzopf
Assistant Examiner—Walter E. Snow
Attorney, Agent, or Firm—Chernoff, Vilhauer, McClung & Stenzel

[57] **ABSTRACT**

A portable transmit/receive induction balance type metal detector having an automatic ground exclusion balance (GEB) feature to facilitate the screening out of the effects of mineralized ground. The circuitry provides a static GEB in a single try and then, if selected by the user, continual automatic GEB on a dynamic basis as the system is used. The circuit includes a pair of quadrature phase detectors, one of whose outputs is approximately in phase with the ground component of the loop return signal. That output is modified, during an air balance of the detector, to remove the residual offsets in the circuit. This modified output in turn is summed with the other phase detector output to produce a phase detection signal that can be adjusted by automatic means to be precisely in quadrature with the ground component of the loop return signal. A controller is provided, with selectable user inputs, to initiate the static and dynamic GEB operations. An error amplifier in conjunction with two sample/hold elements and a variable duty cycle chopper operate in a feedback loop to appropriately adjust the phase detection signal. Audible beep indications are generated to signal the user when the steps in the automatic GEB are completed.

6 Claims, 15 Drawing Sheets



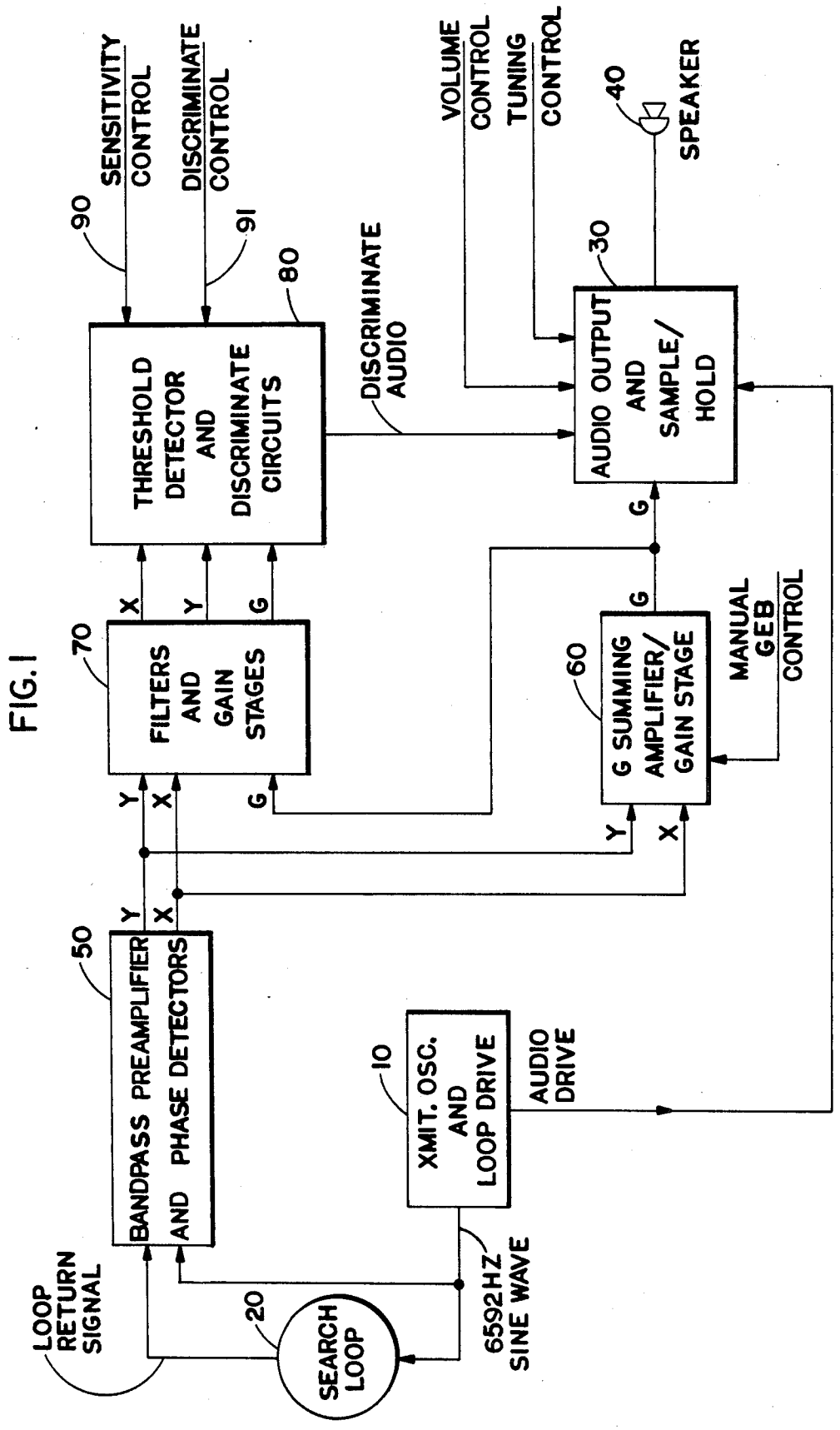

SENSITIVITY CONTROL
DISCRIMINATE CONTROL
VOLUME CONTROL
TUNING CONTROL
SPEAKER
90
91
80
30
40
THRESHOLD DETECTOR AND DISCRIMINATE CIRCUITS
DISCRIMINATE AUDIO
AUDIO OUTPUT AND SAMPLE/ HOLD
X
Y
G
70
FILTERS AND GAIN STAGES
60
G SUMMING AMPLIFIER/ GAIN STAGE
MANUAL GEB CONTROL
50
BANDPASS PREAMPLIFIER AND PHASE DETECTORS
10
XMIT. OSC. AND LOOP DRIVE
AUDIO DRIVE
LOOP RETURN SIGNAL
20
SEARCH LOOP
6592HZ SINE WAVE

FIG. 1

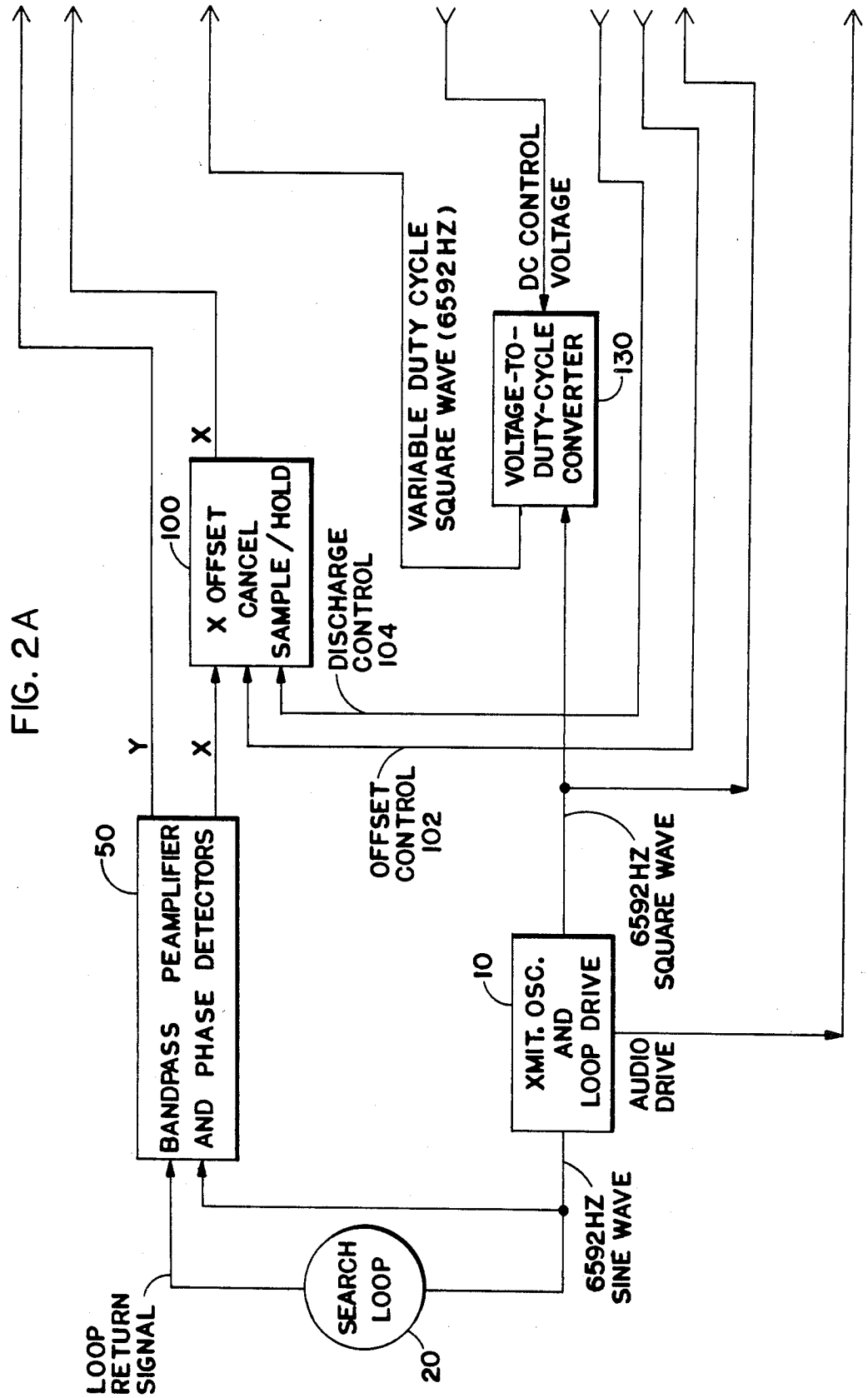

LOOP RETURN SIGNAL
SEARCH LOOP
20
BANDPASS PEAMPLIFIER AND PHASE DETECTORS
50
Y
X
X OFFSET CANCEL SAMPLE / HOLD
100
X
DISCHARGE CONTROL 104
OFFSET CONTROL 102
VARIABLE DUTY CYCLE SQUARE WAVE (6592 HZ)
VOLTAGE-TO-DUTY-CYCLE CONVERTER
130
DC CONTROL VOLTAGE
XMIT. OSC. AND LOOP DRIVE
10
6592HZ SINE WAVE
6592HZ SQUARE WAVE
AUDIO DRIVE

FIG. 2A

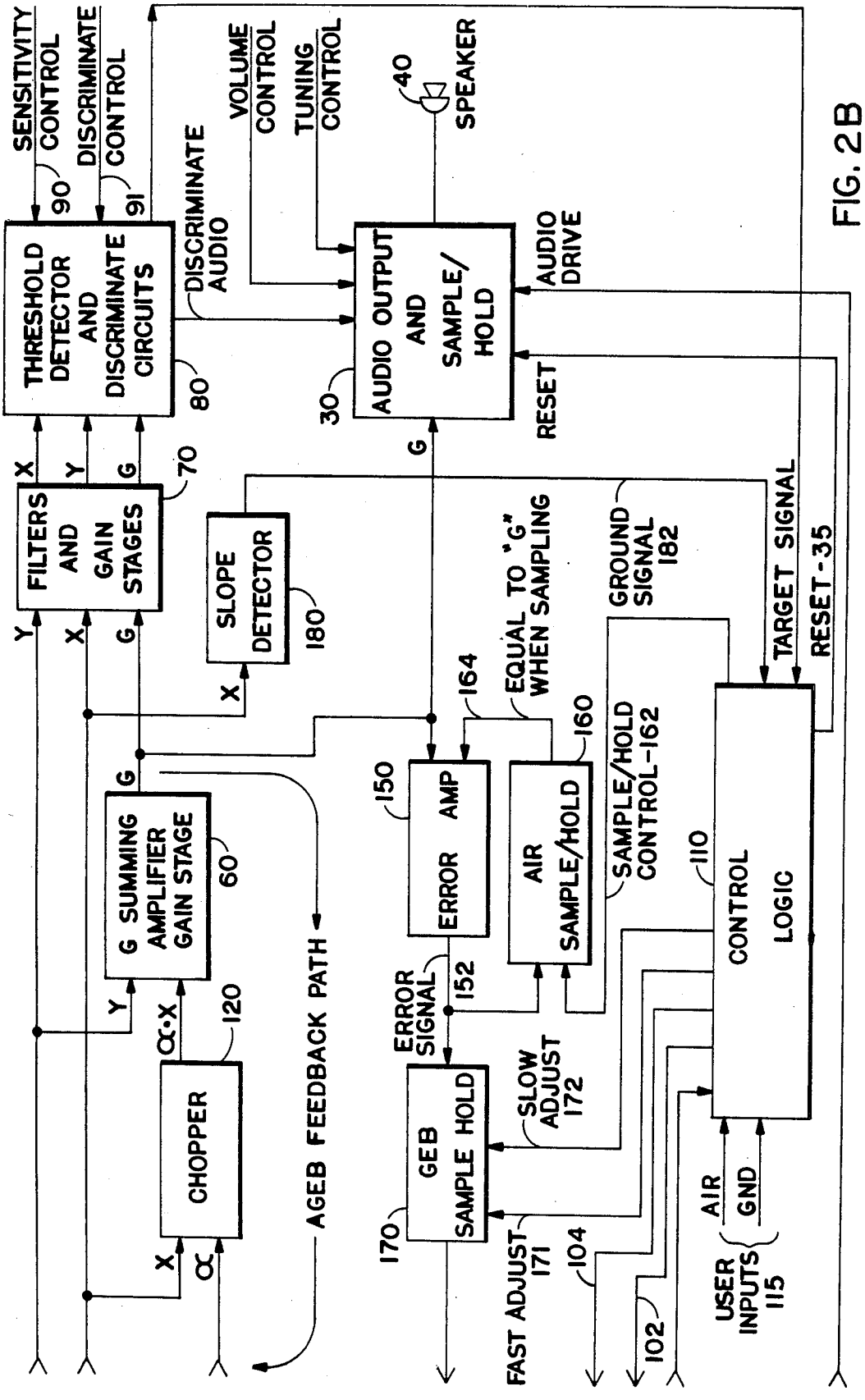
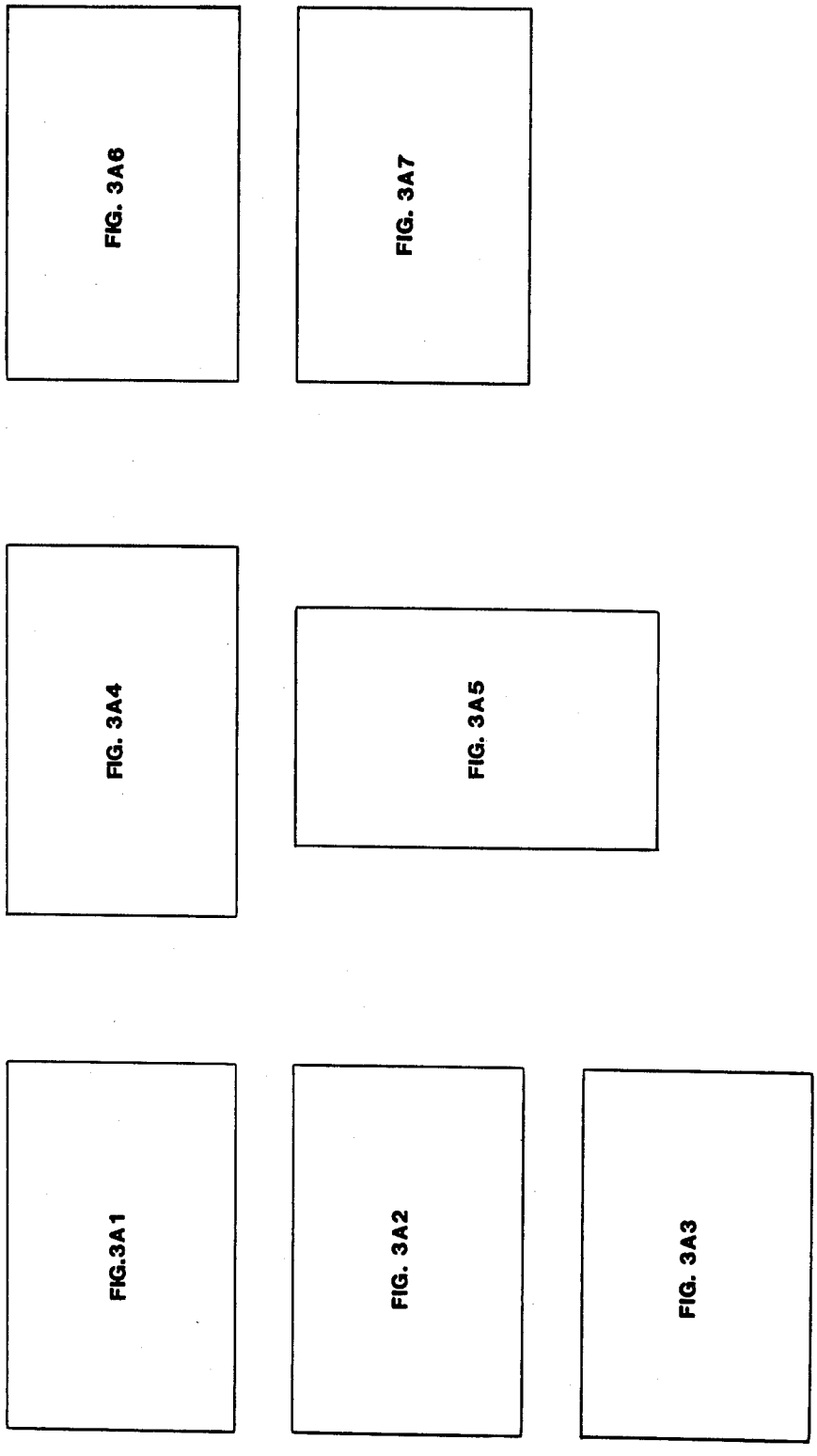

SENSITIVITY CONTROL
90
DISCRIMINATE CONTROL
91
VOLUME CONTROL
TUNING CONTROL
40
SPEAKER
THRESHOLD DETECTOR AND DISCRIMINATE CIRCUITS
80
DISCRIMINATE AUDIO
AUDIO OUTPUT AND SAMPLE/HOLD
30
AUDIO DRIVE
RESET
FILTERS AND GAIN STAGES
70
SLOPE DETECTOR
180
GROUND SIGNAL 182
TARGET SIGNAL
RESET-35
EQUAL TO "G" WHEN SAMPLING
164
150
ERROR AMP
AIR SAMPLE/HOLD
160
SAMPLE/HOLD CONTROL-162
110
CONTROL LOGIC
G SUMMING AMPLIFIER GAIN STAGE
60
CHOPPER
120
AGEB FEEDBACK PATH
ERROR SIGNAL
152
SLOW ADJUST 172
GEB SAMPLE HOLD
170
FAST ADJUST 171
104
102
AIR
GND
USER INPUTS 115

FIG. 2B

FIG. 3A0



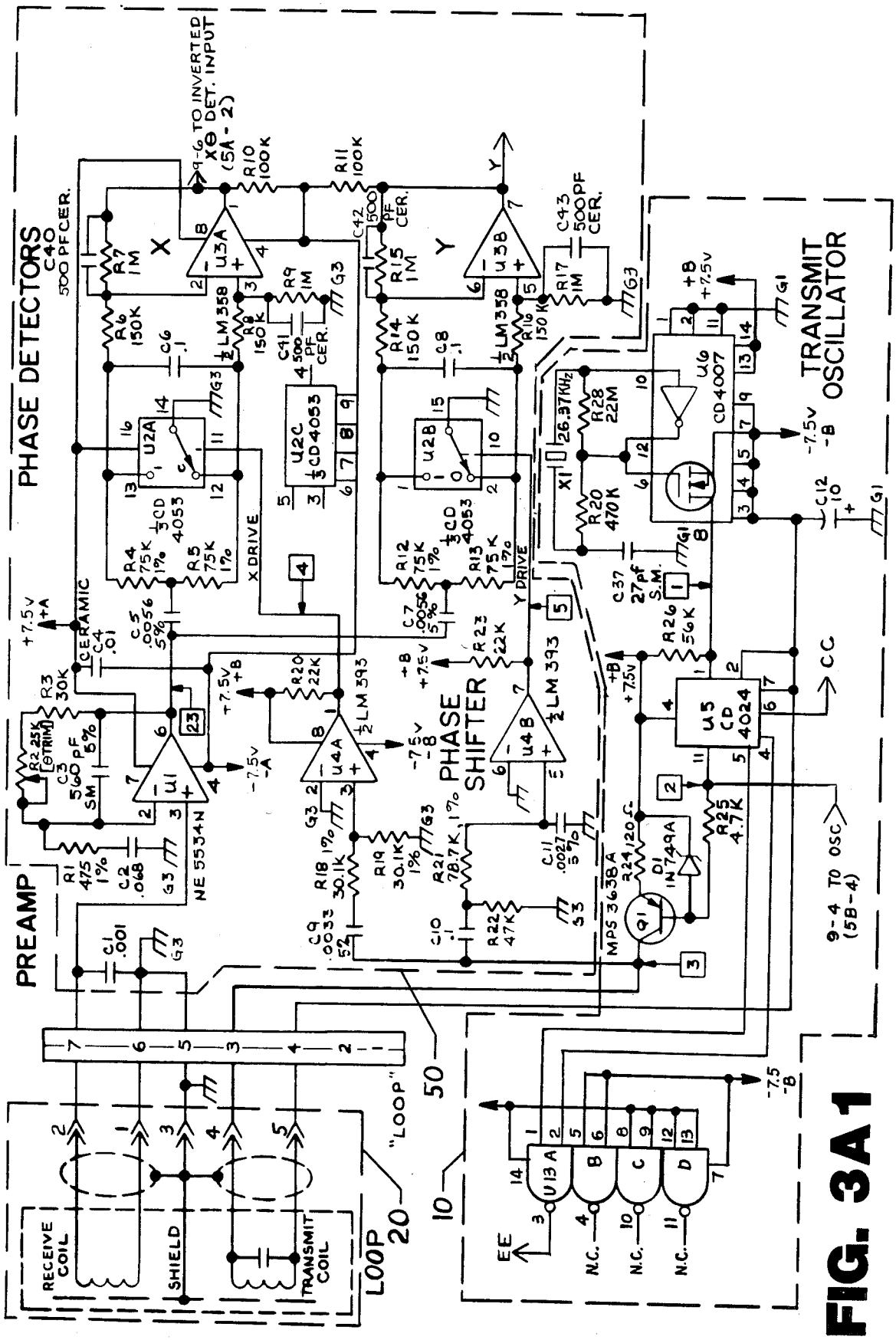

PREAMP
PHASE DETECTORS
PHASE SHIFTER
TRANSMIT OSCILLATOR
X
Y
X DRIVE
Y DRIVE
CERAMIC
NE 5534N
LM 393
CD 4024
CD4007
MPS 3638A
1N749A
26.37KHz
RECEIVE COIL
SHIELD
TRANSMIT COIL
LOOP
"LOOP"
9-6 TO INVERTED X0 DET. INPUT (5A-2)
9-4 TO OSC (5B-4)
+7.5v +A
-7.5v -A
+B +7.5v
-7.5v -B
+8
-8
CC
EE
N.C.
N.C.
N.C.

FIG. 3A1

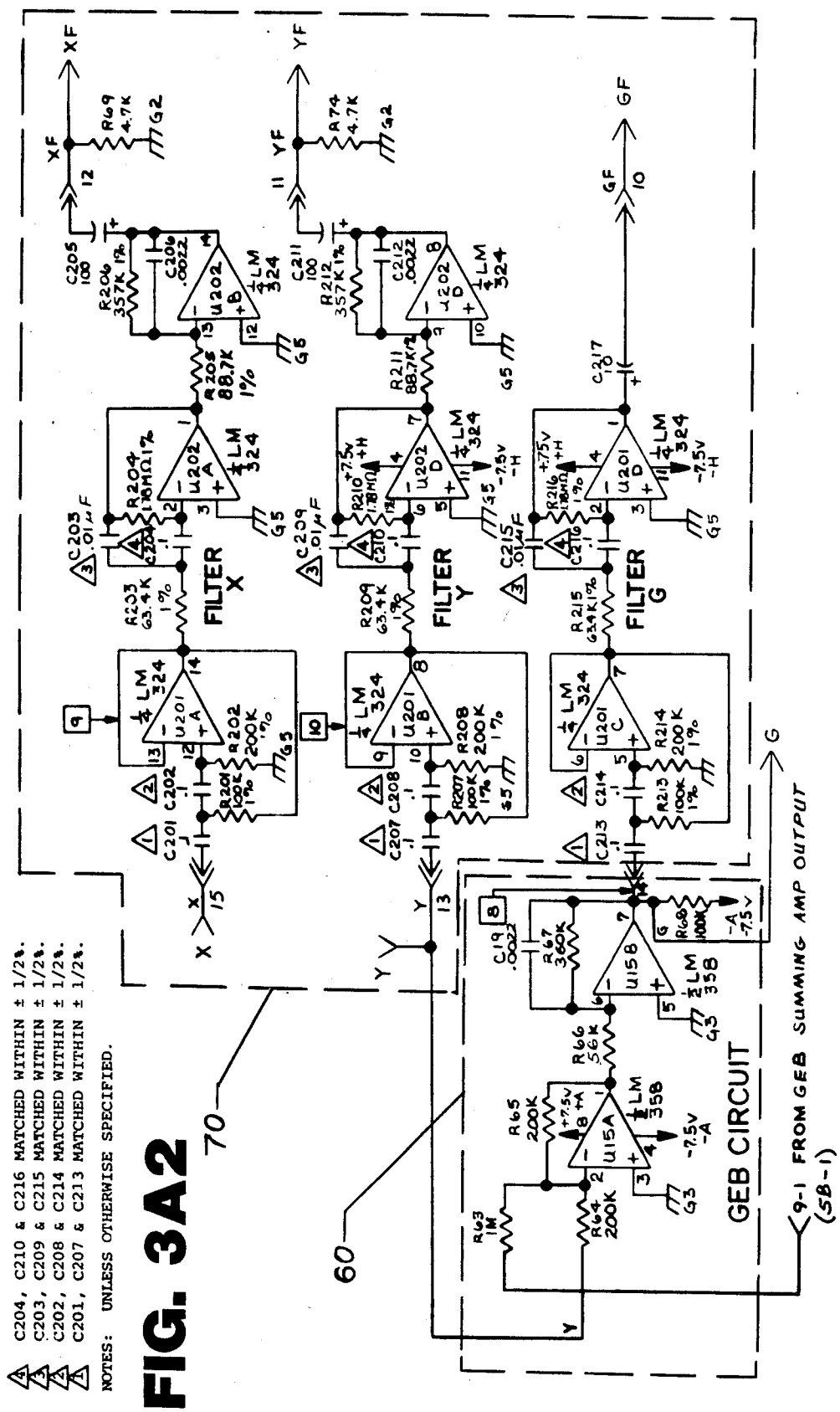

XF
YF
GF
FILTER X
FILTER Y
FILTER G
GEB CIRCUIT
70
60
9-1 FROM GEB SUMMING AMP OUTPUT (5B-1)
NOTES: UNLESS OTHERWISE SPECIFIED.
C204, C210 & C216 MATCHED WITHIN ± 1/2%.
C203, C209 & C215 MATCHED WITHIN ± 1/2%.
C202, C208 & C214 MATCHED WITHIN ± 1/2%.
C201, C207 & C213 MATCHED WITHIN ± 1/2%.

FIG. 3A2

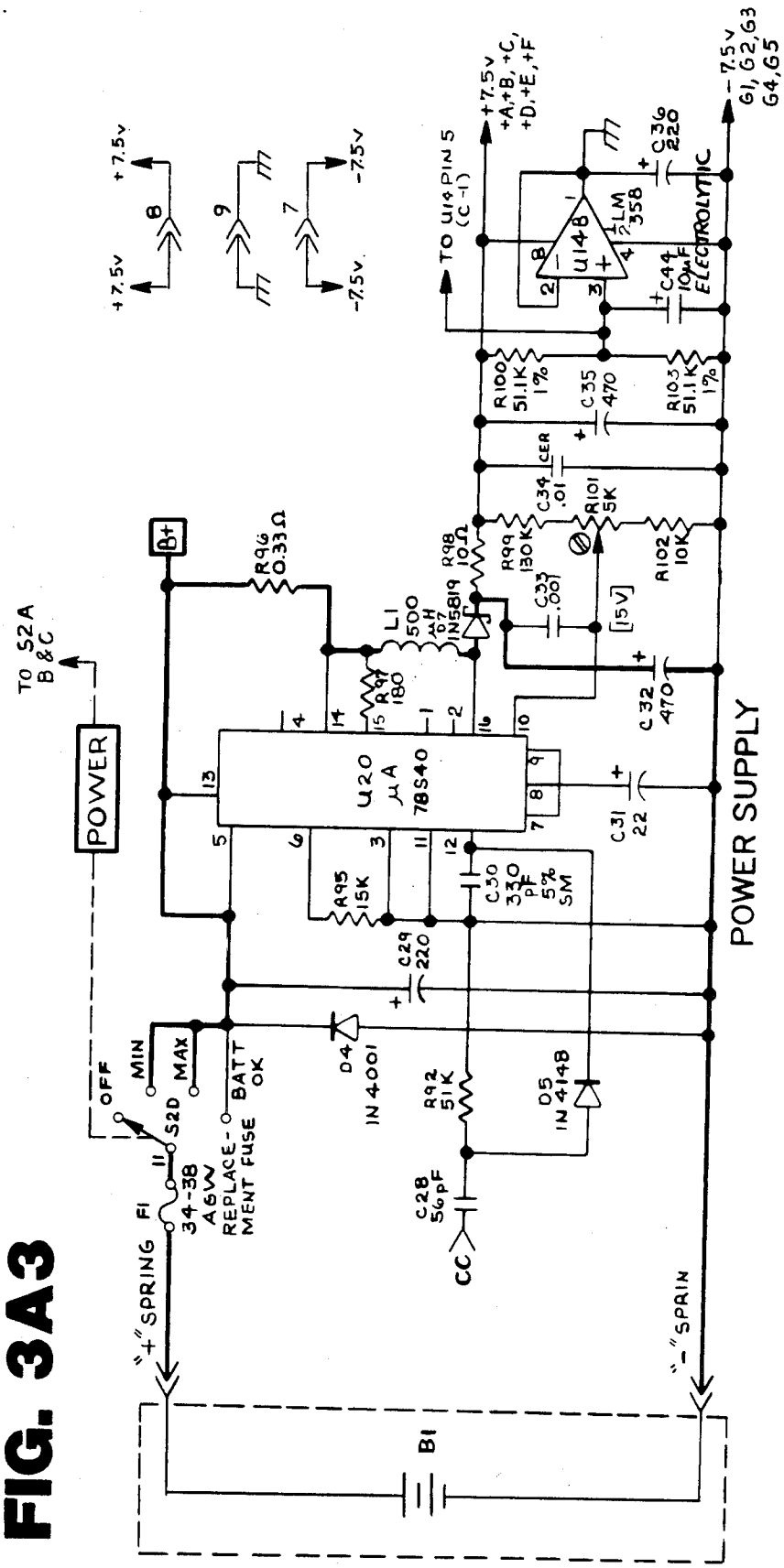

POWER SUPPLY
POWER
TO 52A B&C
B+
R96 0.33Ω
L1 500 uH
1N5819
R97 180
R98 10Ω
R99 130K
C34 .01
R101 5K
R102 10K
C33 .001
[15V]
C32 470
U20 μA 78S40
C31 22
R95 15K
C30 330 pF 5% SM
C29 220
C28 56pF
CC
D4 IN4001
R92 51K
D5 IN4148
S2D
OFF
MIN
MAX
BATT OK
REPLACE-MENT FUSE
34-38 AGW
F1
"+" SPRING
"-" SPRIN
B1
TO U14 PIN 5 (C-1)
+7.5V +A,+B,+C, +D,+E,+F
-7.5V G1,G2,G3 G4,G5
U14B
1/2 LM 358
C36 220
C44 10μF ELECTROLYTIC
R100 51.1K 1%
C35 470
R103 51.1K 1%
+7.5V
-7.5V
8
9
7

FIG. 3A3

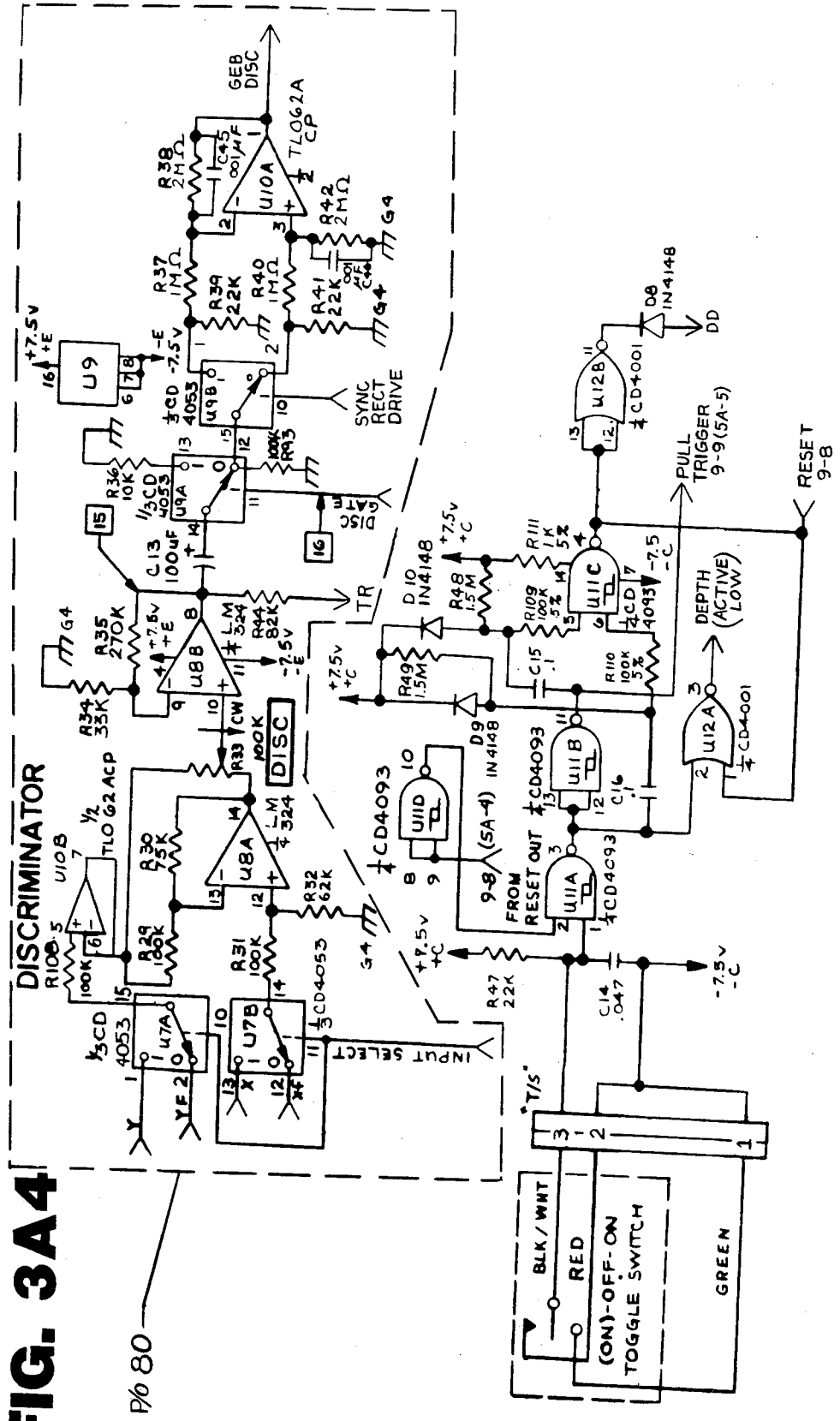
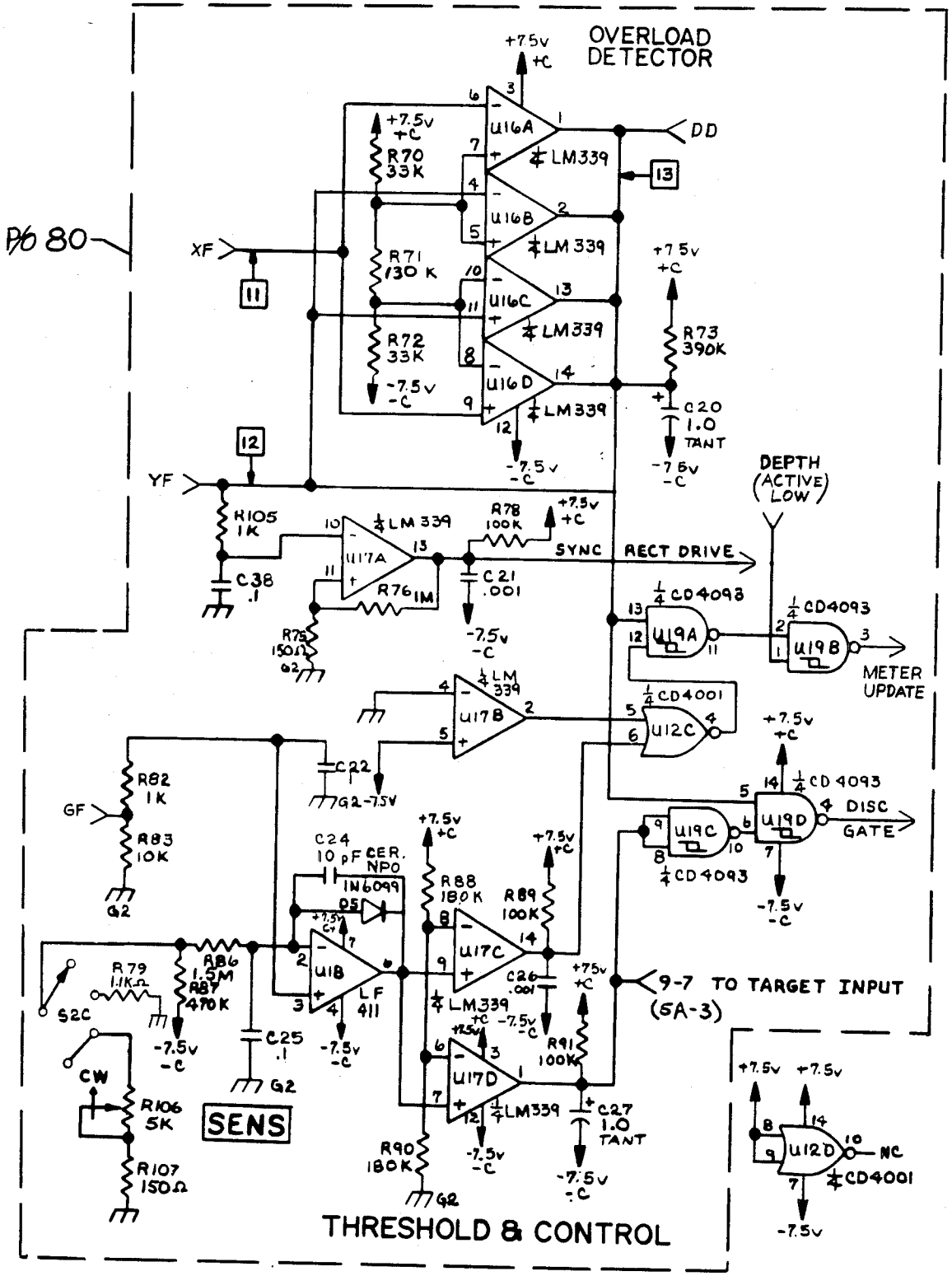

DISCRIMINATOR
GEB DISC
TLO62A CP
U10A
R38 2MΩ
C45 .001μF
R42 2MΩ
R37 1MΩ
R39 22K
R40 1MΩ
R41 22K
C44 .001
U9
+7.5v +E
-7.5v -E
1/3CD 4053 U9B
SYNC RECT DRIVE
R36 10K
1/3CD 4053 U9A
R43 100K
DISC
C13 100uF
R35 270K
R34 33K
U8B
LM 324
R44 82K
TR
R33 100K CW
DISC
U10B
TLO62 ACP
R100 100K
R30 75K
R29 100K
U8A
R32 62K
R31 100K
1/3CD 4053 U7A
1/3CD 4053 U7B
1/3CD4053
INPUT SELECT
YF 2
Y
P/O 80
D10 IN4148
R48 1.5M
R49 1.5M
D9 IN4148
R111 1K 5%
R109 100K 5%
R110 100K 5%
C15 .1
U11C
1/4CD 4093
-7.5 -C
U11B
U11D
U11A
1/4CD4093
9-8 (SA-4)
FROM RESET OUT
C16 .1
U12B
1/4CD4001
D8 IN4148
DD
PULL TRIGGER 9-9(SA-5)
RESET 9-8
DEPTH (ACTIVE LOW)
U12A
1/4CD4001
R47 22K
C14 .047
T/S
BLK/WHT
RED
GREEN
(ON)-OFF-ON TOGGLE SWITCH

FIG. 3A4

FIG. 3A5


OVERLOAD DETECTOR
+7.5v +C
U16A
LM339
DD
R70 33K
R71 130 K
R72 33K
-7.5v -C
U16B
U16C
U16D
R73 390K
C20 1.0 TANT
XF
YF
P/O 80
R105 1K
C38 .1
U17A
R76 1M
R78 100K
SYNC
RECT DRIVE
C21 .001
DEPTH (ACTIVE LOW)
CD4098
U19A
CD4093
U19B
METER UPDATE
U17B
CD4001
U12C
R82 1K
R83 10K
GF
G2
C22
C24 10 pF CER. NPO
IN6099
R88 180 K
R89 100K
U17C
C26 .001
R91 100K
9-7 TO TARGET INPUT (5A-3)
U19C
U19D
DISC GATE
R79 1.1K
R86 1.5M
R87 470K
S2C
U18
LF 411
C25 .1
CW
R106 5K
R107 150Ω
SENS
U17D
C27 1.0 TANT
R90 180K
U12D
NC
THRESHOLD & CONTROL

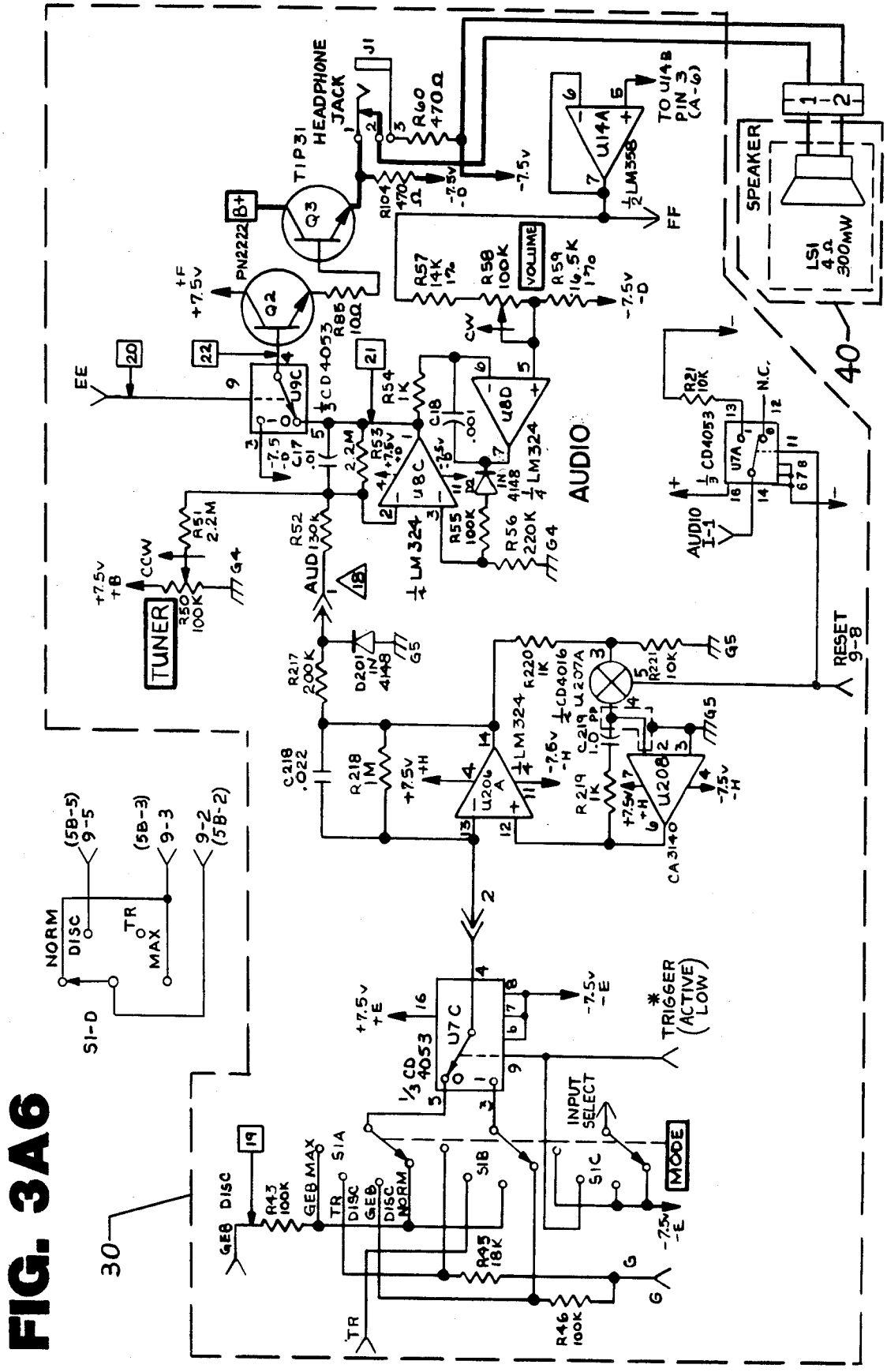

AUDIO
HEADPHONE JACK
TIP31
PN2222
SPEAKER
VOLUME
TUNER
RESET
TRIGGER (ACTIVE LOW)
INPUT SELECT
MODE
NORM
DISC
TR
MAX
CA3140
LM324
CD4053
CD4016
LM358

FIG. 3A6

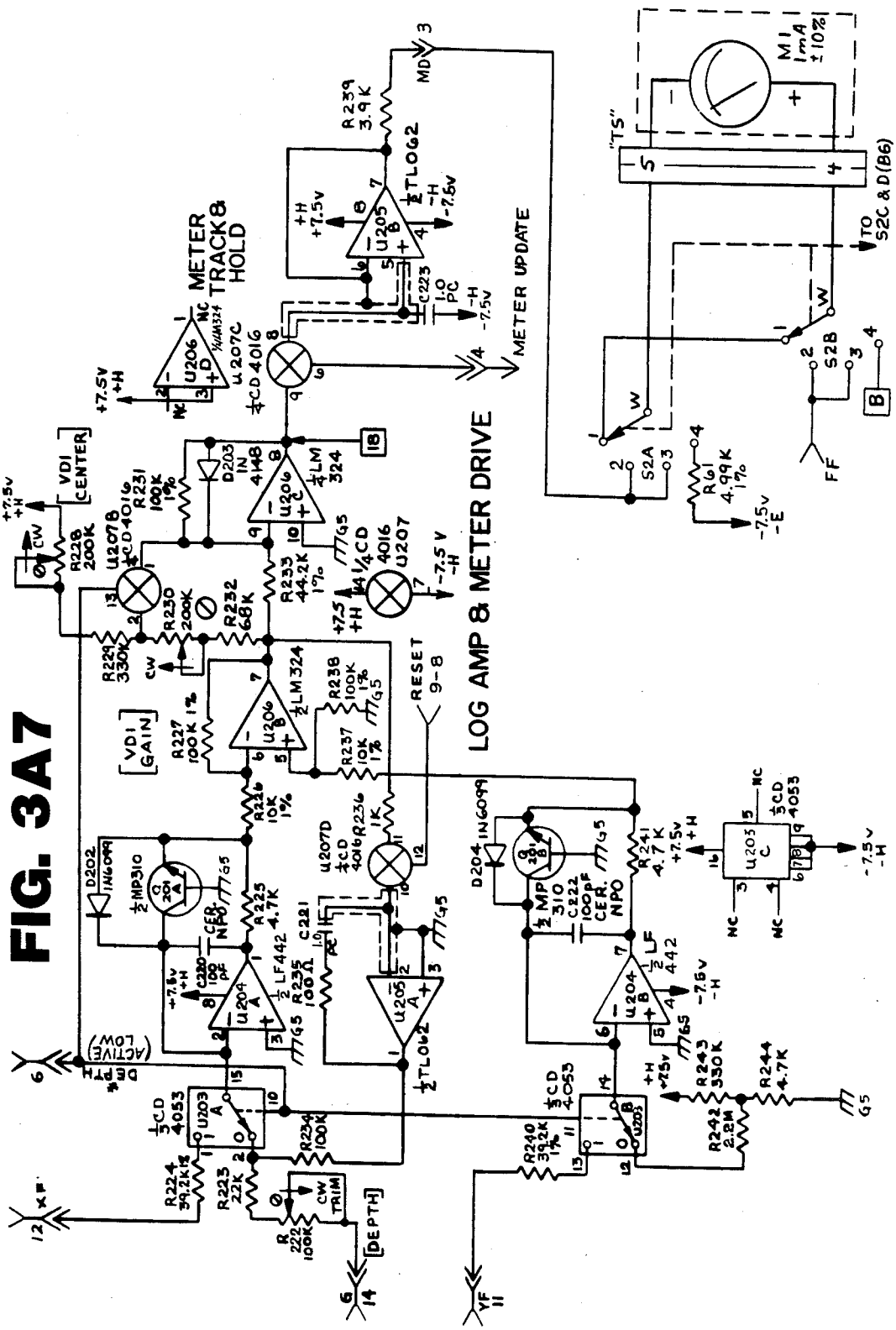

LOG AMP & METER DRIVE
METER TRACK & HOLD
METER UPDATE
RESET 9-8
VDI CENTER
VDI GAIN
DEPTH
TO S2C & D(B6)
M1 1mA ±10%
"TS"
S2A
S2B
FF
R61 4.99K 1%
-7.5v -E
R239 3.9K
R231 100K 1%
R228 200K
R230 200K
R232 68K
R233 44.2K 1%
R229 330K
R238 100K 1%
R237 10K 1%
R227 100K 1%
R226 10K 1%
R236 1K
R241 4.7K
R225 4.7K
R235 100Ω
R234 100K
R224 34.2K 1%
R223 22K
R222 100K
R240 392K 1%
R242 2.2M
R243 330K
R244 4.7K
C223 1.0 PC
C222 100pF CER. NPO
C221 1.0 PC
C220 100 pF
U206 1/4 LM324
U207 1/4 CD 4016
U204 1/2 LF442
U205 1/2 TL062
U203 1/3 CD 4053
D202 IN6099
D203 IN 4148
D204 IN6099
Q201 2N5457
Q202 2N5457
+7.5v +H
-7.5v -H
-7.6v -H
CW
CW TRIM
(ACTIVE LOW)
XF
YF

FIG. 3A7

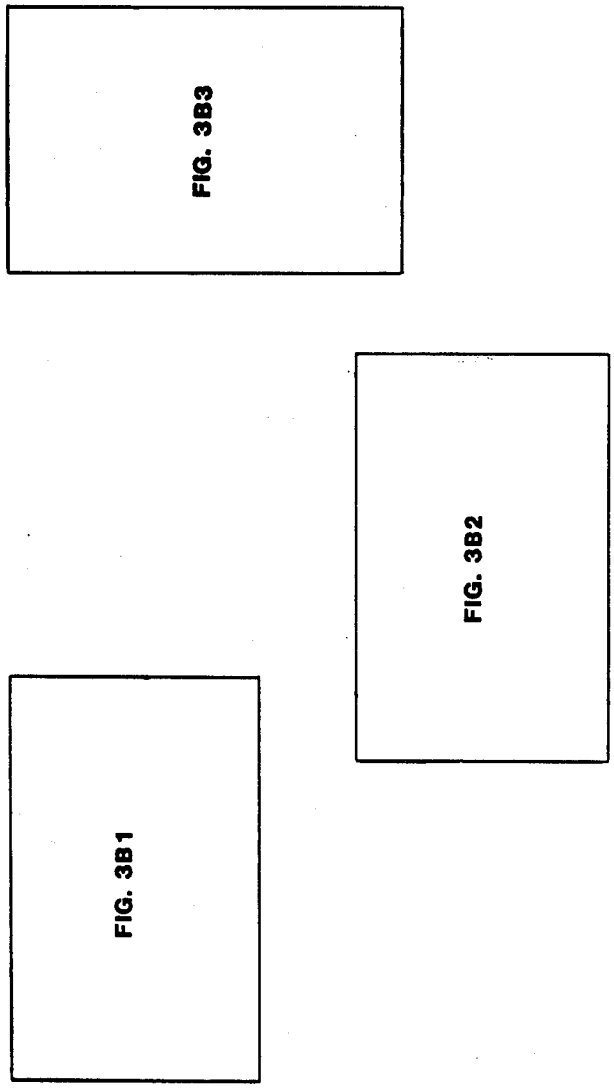


FIG. 3BØ

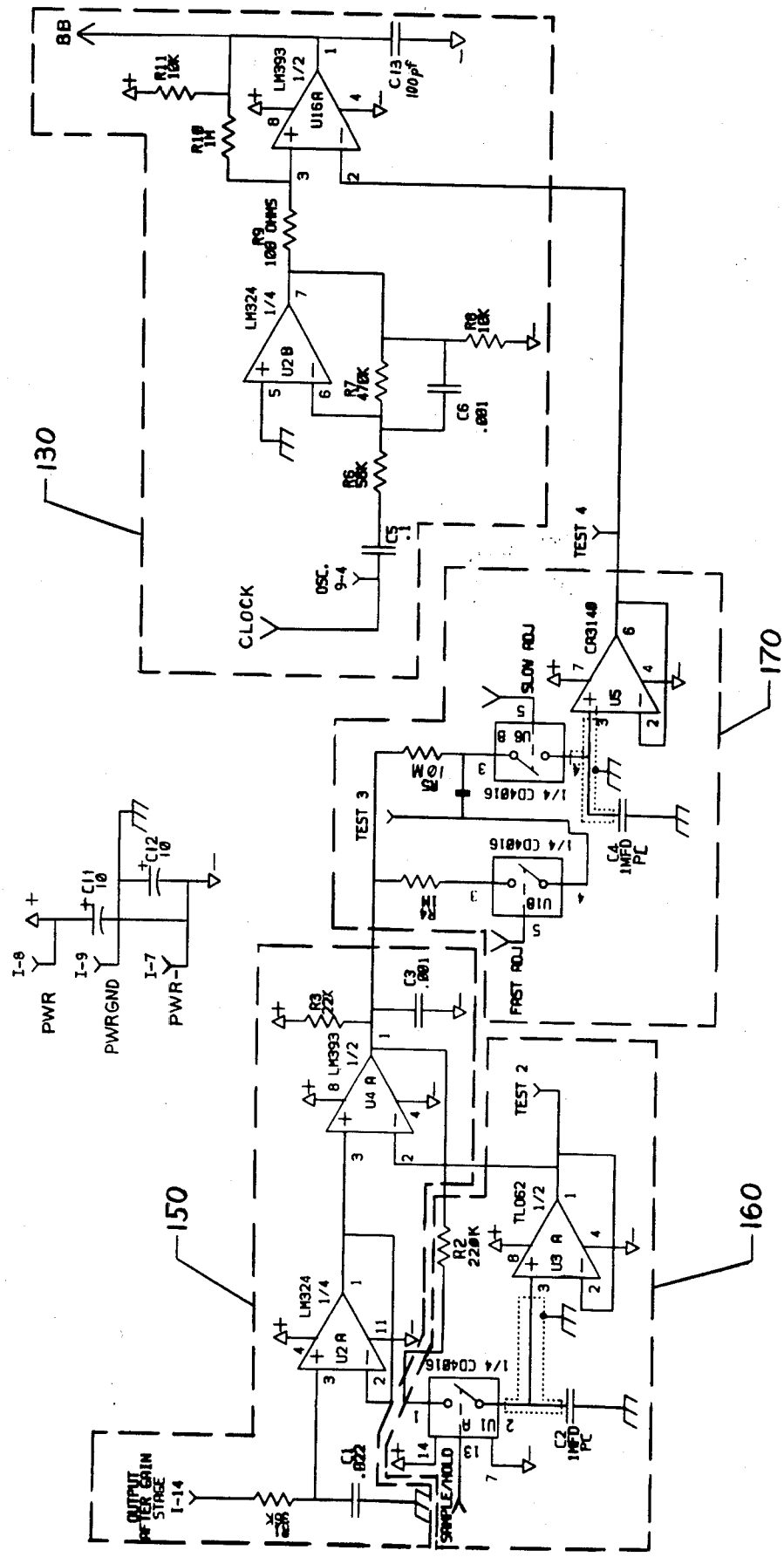

8B
R11 16K
LM393 1/2
U16A
C13 100pf
R10 1M
R9 100 OHMS
LM324 1/4
U2B
R8 16K
R7 470K
C6 .001
R6 50K
C5 .1
130
OSC. 9-4
CLOCK
TEST 4
SLOW ADJ
CR3140
U5
170
R5 10M
1/4 CD4016
C4 1MFD PC
TEST 3
U18
R4
FAST ADJ
I-8
PWR
I-9
PWRGND
I-7
PWR-
C11 10
C12 10
C3 .001
R3 22K
LM393 1/2
U4 A
TEST 2
150
160
R2 22K
TL062 1/2
U3 A
LM324 1/4
U2A
1/4 CD4016
U1
C2 1MFD PC
C1 .022
OUTPUT AFTER GAIN STAGE
I-14
SAMPLE/HOLD

FIG. 3B1

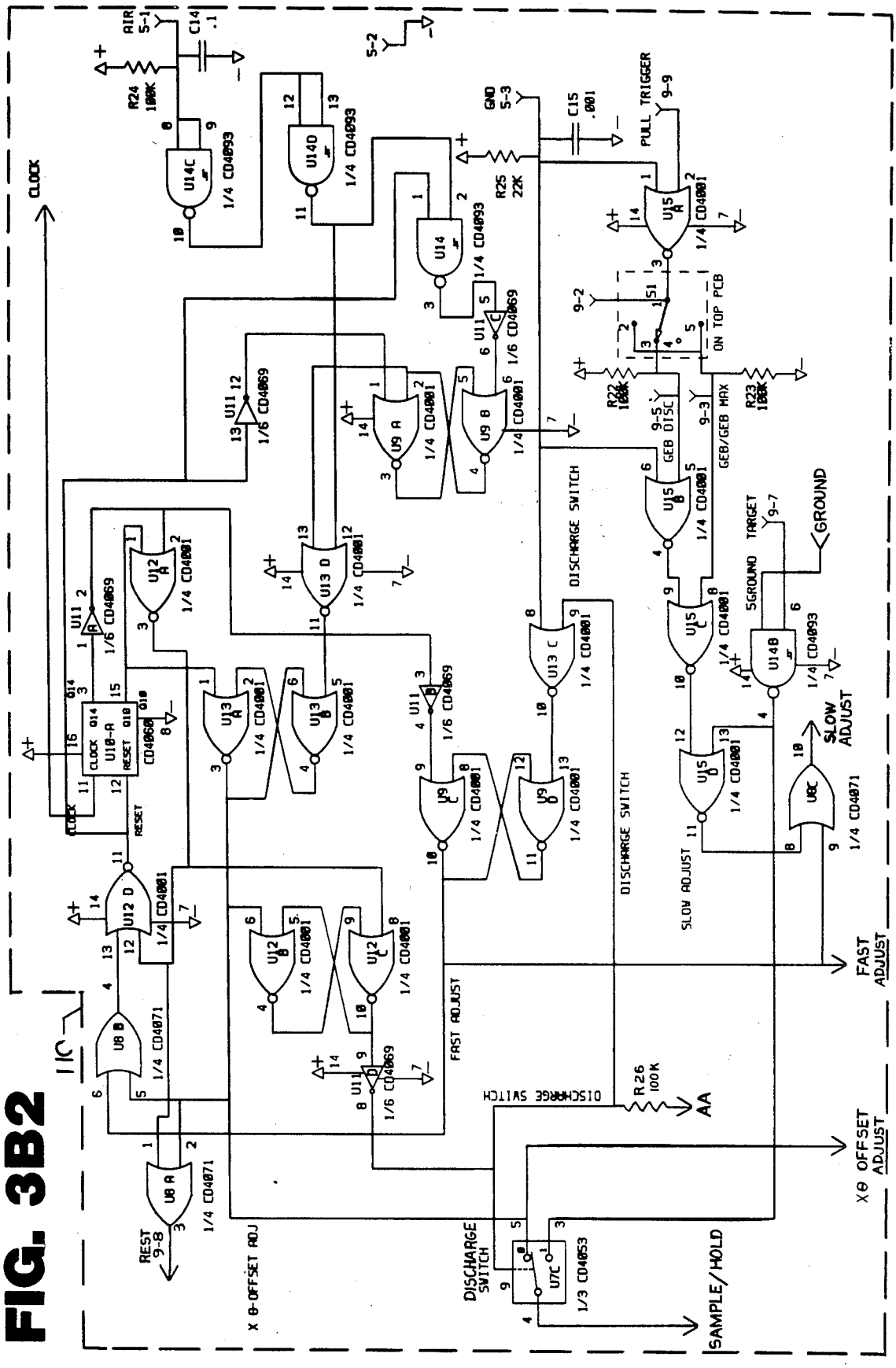
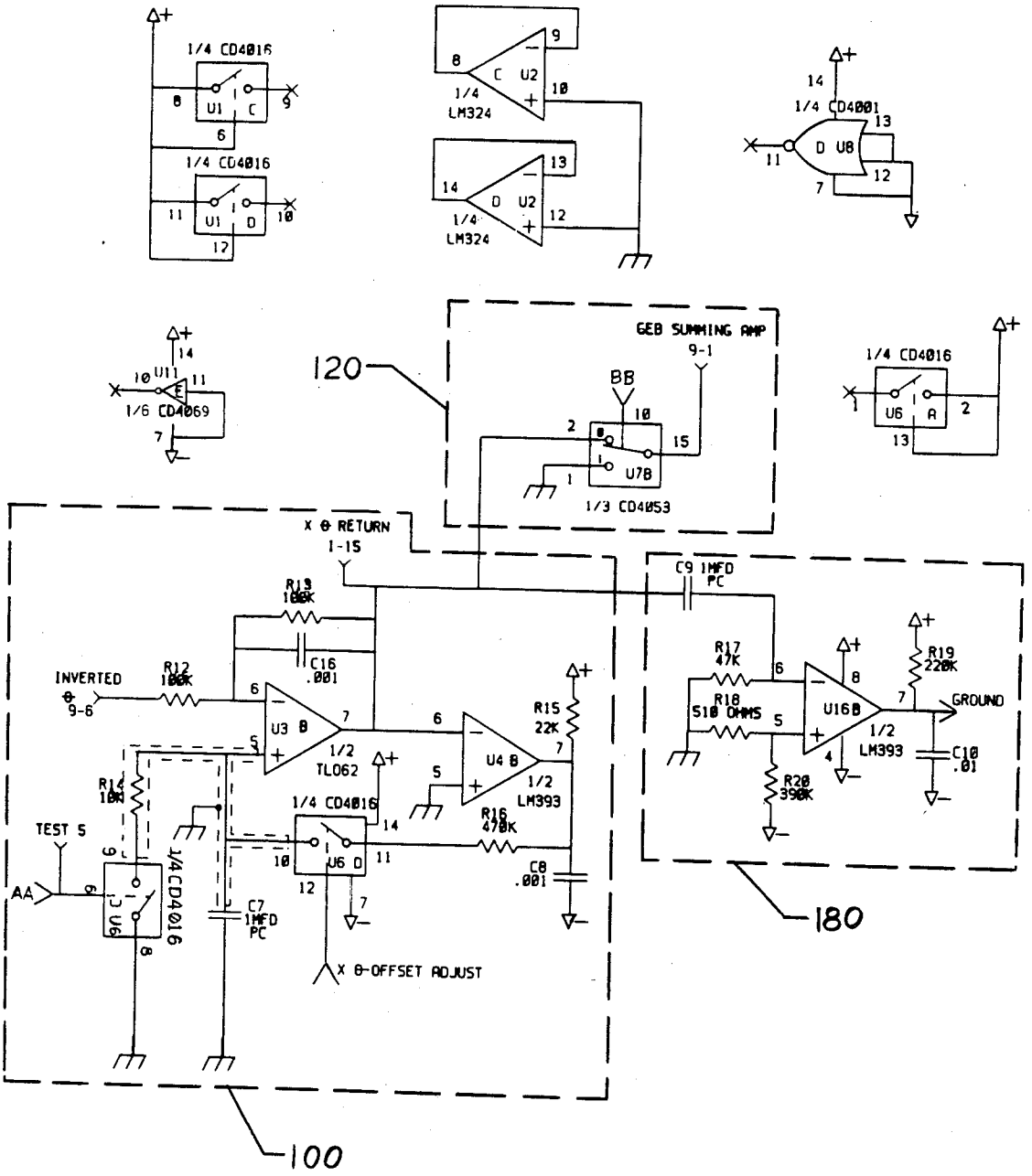

CLOCK
AIR
S-1
C14
.1
R24
S-2
GND
S-3
C15
.001
PULL TRIGGER
9-9
R25
22K
U14C
U14D
U14
U15A
1/4 CD4093
1/4 CD4001
1/6 CD4069
9-2
S1
ON TOP PCB
R22
R23
9-5
GEB DISC
9-3
GEB/GEB MAX
U9 A
U9 B
U11 12
DISCHARGE SWITCH
U12 A
U12 D
U13 D
U13 C
U15B
U15C
U15D
SGROUND
TARGET
9-7
GROUND
U14B
SLOW ADJUST
U16-A
CLOCK Q14
RESET Q10
CD4060B
U13 A
U13 B
U9 C
U9 D
U12 B
U12 C
U8C
1/4 CD4071
FAST ADJUST
U8 B
U8 A
R26
100K
AA
REST
9-8
X θ-OFFSET ADJ
DISCHARGE SWITCH
U7C
1/3 CD4053
SAMPLE/HOLD
X θ OFFSET ADJUST

FIG. 3B2

FIG. 3B3


1/4 CD4016
U1
1/4 CD4016
U1
1/4 LM324
U2
1/4 LM324
U2
1/4 CD4001
U8
1/6 CD4069
U11
GEB SUMMING AMP
9-1
120
BB
U7B
1/3 CD4053
1/4 CD4016
U6
X θ RETURN
1-15
C9 1MFD PC
R19 100K
C16 .001
INVERTED θ 9-6
R12 100K
U3 B
1/2 TL062
U4 B
1/2 LM393
R15 22K
R16 470K
1/4 CD4016
U6 D
C8 .001
TEST 5
AA
1/4CD4016
U6
C7 1MFD PC
X θ-OFFSET ADJUST
100
R17 47K
R18 510 OHMS
U16B
1/2 LM393
R19 220K
GROUND
C10 .01
R20 390K
180

METAL DETECTOR WITH CIRCUITS FOR AUTOMATICALLY SCREENING OUT THE EFFECTS OF OFFSET AND MINERALIZED GROUND

BACKGROUND OF THE INVENTION

The present invention relates to an apparatus and method for providing automated ground exclusion balance in portable hand-held metal detectors of the induction balance transmit/receive type in popular use today for searching and finding metal objects lying on or buried just beneath the surface of the ground. Such detectors are held by the operator and moved or swept over the surface of the ground, and, when the detector passes over a metal object, the disturbance of a magnetic field created in the area of the detector's search loop, as generated by a transmit coil signal and monitored by a receive coil, unbalances the coil loop circuit and causes the detector to produce a visual or audible indication of the presence of the metal object. Such instruments have in recent years become quite sophisticated in operation, sufficiently so that, by responding not only to the amplitude of the magnetic field disturbance but also to the shift in the phase angle of the received or target signal relative to the transmitted signal, an approximate indication can be provided by the detector as to the type of metal object located, e.g. coins as opposed to aluminum pull-tabs, and even as to the type of metal coin involved, penny, nickel, dime, quarter, etc. However, before utilizing these detectors to search for and locate metal objects it is first necessary to adjust the loop circuit to screen out the effects of the mineralized ground in the area. The compensation or adjustments to the detector's search head loop circuit for such earth effects, referred to herein as "ground exclusion balance" or, more simply, "GEB," was commonly carried out prior to the present invention by cut-and-try manual techniques in which the operator would first reset the detector instrument in air to cancel all offsets and to set a low but discernible audio tone level in the detector, and then hold it on or just above a patch of ground known or believed to be free of metal objects. The change from air to ground typically would cause either a marked decrease or increase in the audio tone, and the operator would next respond by changing, through manipulation of a knob setting on the instrument, the parameters of its detector circuitry to change the tone level in the opposite direction. The operator would then repeat the reset step, again change the ground balance setting, and continue this sequence as many times as necessary until the change in tone level in going from air to ground, or back, was either eliminated or reduced to an acceptable minimum level. Such manual GEB adjustment, as can readily be appreciated from the foregoing description, was tedious and time-consuming, and the procedure had to be repeated whenever the mineralization content of the ground changed appreciably as the operator worked over an area.

SUMMARY OF THE INVENTION

The present invention provides a control logic circuit means for automating this GEB operation, both staticly and dynamically, the latter referring to the GEB function being performed by the instrument on a continual, automatic basis as the detector is used to search over an area. As a consequence the operator, using a metal detector with this feature, can quickly set the instrument for search and find activity, with the offset or adjustment in the loop circuit required to screen out the ground mineralization effects provided automatically, and then have this screening in effect, without further ado, as he/she proceeds over an area even though the ground's mineralization content might change dramatically.

In an exemplary embodiment of the present invention an air balancing operation is performed by the instrument's circuit, in response to operator switch actuation, while momentarily holding the unit with its search head up in the air and away from any metal objects. An audible beep tone signals the completion of this "air balance" cycle. The operator then places the loop on or very near the ground and switches the instrument to the "ground balance" cycle. The instrument's control logic circuit then proceeds to automatically make the necessary changes in the loop circuit parameters to accomplish ground effect elimination, and when this step is completed a second audible beep occurs, thus signaling that the instrument is ready for use. The user can then, if desired, empirically confirm that the instrument is indeed ground balanced by listening for any change, in either direction, in the threshhold tone as the loop is moved over the ground in an area free of targets. After this static GEB has been accomplished the operator can, if desired, maintain the detector in ground balance automatically as he/she uses it. The instrument is provided with a self-adjusting, or dynamic, ground balancing feature which, as the loop is swept over the ground, a tracking circuit operates, under operator switch selection, to automatically incrementally adjust the loop's circuit parameters, as needed, to maintain the unit in ground balance even as the mineralization content of the soil changes. The instrument, in the illustrative embodiment herein described, is also provided with a sensitivity-adjustable knob setting to enable the user to regulate the operation of the tracking circuit so that target objects within the instrument's range will not inadvertently be tuned out. In a preferred form of the invention the detector is additionally provided with a user-selectable "preset" or factory fixed setting on its sensitivity control which enables a novice operator to obtain satisfactory performance with the unit with a minimum of fuss (however, an experienced user will invariably desire to set his/her own level of sensitivity in the instrument, particularly when searching unusual terrain.) Selection of the preset setting on sensitivity locks out the sensitivity knob control and prevents the user from turning the sensitivity control up so much that the ground balance tracking circuit does not work properly. Use of the preset setting enables the instrument to be used effectively after a short while, even without performing the GEB steps referred to previously, as sweeping of the detector back and forth over the ground in searching will cause the tracking circuit to eventually, in about 30 to 50 sweeps (the number required being determined by the amount the instrument is initially off-range from the GEB condition), bring the loop circuit into ground balance. In the tracking circuit provided in the automated GEB system of the present invention the adjustment in the detector circuit's parameters is made on each sweep of the search head as it approaches the low point nearest to the ground. Thus, for best results, the operator should implement the initial, or static, GEB with the loop resting on or very near the ground, and then search by sweep-

ing the loop as close to the ground as possible. If condition of the ground changes as the operator moves about the area the tracking circuit will adjust the loop circuit to keep the instrument in ground balance at all times without need for operator intervention.

Other objectives, features and advantages of the invention will be apparent upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an illustrative example of a metal detector of the induction balance transmit/-receive balance type, with no provision for an automatic ground exclusion balance feature.

FIGS. **2A** and **2B** block diagram of the metal detector embodiment of FIG. **1** modified to include an automatic ground exclusion balance feature in accordance with the present invention.

FIGS. **3A0–3A7** and **3B0–3B3** are electrical schematic diagrams of an exemplary circuit embodiment of the metal detector of FIG. **2** having the automatic ground exclusion balance feature of the present invention.

FIGS. **3A0** and **3B0** are diagrams illustrating the layout arrangement of the electrical schematic diagrams of FIGS. **3A1** to **3A7** and **3B1** to **3B3** respectively.

DETAILED DESCRIPTION OF THE INVENTION

An illustrative embodiment of a metal detector of the described type having the automatic ground exclusion balance (AGEB) feature of the present invention is currently manufactured and marketed by applicant's assignee, White's Electronics, Inc., of Sweet Home, Oreg., under the model name and trademark COIN-MASTER 6000/Di Professional (hereinafter referred to as the "6000/Di Pro").

The operator's manual for the 6000/DiPro instrument, published by White's Electronics, Inc., describes the manner in which the AGEB feature is utilized by the operator through panel switch settings and manipulations of the instrument's search head. While such description has been summarized earlier herein and is non-essential to an understanding of the nature and manner of operation of the present invention, it is useful in understanding its background and operational environment. Accordingly, that publication, to the extent pertinent hereto in respect to the AGEB feature, is herein incorporated by this reference.

Referring first to FIG. **1**, there is shown a simplified block diagram of a transmit/receive type induction balance metal detector, corresponding to the Model 6000/Di Pro, but without the AGEB feature included. The instrument comprises a Transmit Oscillator and Loop Drive **10** which causes a sinusoidal waveform to be produced in to the Search Loop **20** as well as providing an audio tone signal, supplied via Audio Output **30**, to the Speaker **40** which provides an audible indication to the operator of the status of the loop's balance circuit. The Audio Output **30** is preferably provided with a user-actuatable Sample/Hold circuit--a conventional feature--to allow offsets in the input to the audio stage to be cancelled. The Search Loop **20**, as is conventional, comprises a pair of coils—a transmit coil driven by the Transmit Oscillator which generates a magnetic field in the area of the search loop and a receive coil which is responsive to changes in that magnetic field caused by the nearby environment. Targets coming within the area of the transmit coil's field change the loop return signal produced in the receive coil's windings which are connected to a Band Pass Preamplifier and Phase Quadrature Detectors **50**. The Band-Pass Preamplifier portion boosts and buffers the loop return signal and reduces the gain for frequencies far from the Transmit Oscillator's frequency. The Phase Detectors are substantially identical and serve as a balanced demodulator X and Y component quadrature phase detector system. The two respective outputs X and Y of the Phase Detectors are summed in GEB Summing Amplifier **60** and output as a phase shift signal G which is a function of the amplitude of the loop return signal as well as of the difference in phase between the respective transmit and loop return signals. A GEB Control **65** enables the user, prior to the summing, to vary the gain of one of the quadrature signal components, exemplarily X, corresponding to the ground component, while maintaining the gain of the other component at unity. These three phase signals, X, Y and G, are then passed through Filters and Gain Stages **70** and supplied to a Threshold Detector **80** which also includes Discriminater Circuits for responding to and generating as an output to the Speaker **40** an audio indication of the presence of target objects in the field of the search loop. Knob switch/setting controls **90** and **91** are provided to enable the operator to vary, respectively, the degree of sensitivity of the instrument and the degree of discrimination as between target objects of different response characteristics.

The foregoing description is of a conventional metal detector system circuitry in which GEB is effected by the user's manual twiddling and adjustment of the GEB Control setting **65** in the manner described earlier.

FIGS. **2A** and **2B** depict the same simplified metal detector system with the addition of the AGEB feature. (In this diagram elements labeled with the same reference numerals are substantially the same as the similarly-labeled elements in FIG. **1**.) In providing AGEB, offsets in the loop circuit present in the X, or ground component, of the loop return signal, as derived by the Quadrature Phase Detectors **50**, are cancelled out by the X Offset Cancel **100** in response to an appropriate actuating signal **102** from the Control Logic Module **110** when the user selects the "Air" position at **115**. (Offsets refer to the residual DC levels in the output of the Phase Detectors.) The offset to the X component signal is maintained by the Sample/Hold portion of this element **100** until a subsequent time (to be described later) when a disable signal is supplied thereto from the Control Logic module via Discharge Control line **104**. The Summing Amplifier **60** determines the phase G of the loop return signal relative to the transmit signal by inversion summing of a fixed multiple of the Y component with a variable multiple of the X component. The adjustment α applied to the X component at the Summing Amplifier is accomplished through the use of a Chopper **120** whose duty cycle, between zero and 100%, is determined by the DC Control Voltage level **131** applied to Converter **130**. The square wave signal **132** determines the frequency of the Converter's output. In other words, the duration of the duty cycle, corresponding to the adjustment α, is responsive to the output **131** of the GEB Sample/Hold **170**.

In the air balance mode of operation the Error Amplifier **150**, through a feedback loop which is enabled by a control pulse **162** from the Control Logic module,

forces the output **164** of the Air Sample/Hold **160** to match the level of the G signal supplied from the Summing Amplifier **60**. A beep indication, signifying completion of the air balance step, is provided by the Audio Drive **30** upon the enabling of the feedback loop in response to a pulse on the reset line **35** provided by the Control Logic module. Output **164** is held until the ground balance step (described later) is completed. The Error Signal output **152** is provided as an input to GEB Sample/Hold **170** whose function is to provide the Control Voltage level **131**.

In the ground balance mode the Error Amplifier, through an AGEB Feedback Path which is enabled by control signals **171, 172** from the Control Logic module, forces the output of the GEB Sample/Hold to match the G signal supplied from the Summing Amplifier **60** to the output **164** of the Air Sample/Hold. With this matching accomplished, the G signal in ground balance mode has been automatically modified, through adjustment of the X component signal, to equal the G signal level in air balance mode of the detector system. This corresponds to the static balance operation described earlier. When this step is completed the GEB Sample/Hold **170** is caused to hold its output level **131** by the control signals **171, 172**; at the same time the X Offset Cancel **100** is disabled by the control signal **104**. An audio beep indication, signaling that this has occurred, is provided by the Audio Drive **30** in response to a pulse on the reset line **35** provided by the Control Logic module.

If it is desired that the system perform a dynamic ground exclusion balance as earlier described, then the user selects the "Gnd" position at **115**, otherwise this feature is disabled. In the dynamic GEB setting a Slope Detector **180**, responsive to the derivative of the X component signal, provides a Ground Signal **182** whose polarity is indicative of the direction of the X component's slope. For example, a first polarity signifies the Search Loop **20** approaching the ground, and the other polarity, moving away or no movement relative to ground. A change in that signal from the first to the second polarity signifies the point at which the search loop is closest to the ground. As the Search Loop moves away from ground or is static, as monitored by the Slope Detector, the Error Amplifier **150** functions as when in the air balance mode to force the Air Sample/Hold output **164** to match the Summing Amplifier output G. When the Search Loop approaches the ground, the output **164** is held (as before), and in response to a control signal from the Control Logic on the Slow Adjust line **172** the AGEB Feedback Path is closed and the DC Control Voltage **131** is adjusted (as described before) in response to the Error Signal **152** produced upon the matching of Summing Amplifier output G to the Air Sample/Hold output **164**. In this dynamic GEB mode of operation a slow adjustment rate, exemplarily about ten times the time constant of the fast adjustment rate used in the static balance mode, is utilized to limit the speed of the correction provided by the AGEB Feedback Path. This is preferably done, while in this mode, so as to minimize the error which would otherwise occur due to the presence of offsets in the X component signal. (During dynamic balance, it will be recalled, the X Offset Cancel **100** is disabled.) If the unit were left at a fast adjustment rate, for example a circuit time constant of one second as opposed to ten seconds, the circuit would hunt back and forth around the correct GEB setting.

An exemplary electrical schematic of the circuitry of the system, depicted in block diagram form in FIGS. **2A** and **2B**, is shown in FIGS. **3A1–3A7** and **3B1–3B3**. Sections of the circuitry have been partitioned off by dashed lines and labeled with reference numerals corresponding to those of the corresponding elements in the block diagram of FIG. **2**. Component elements in the schematic, and their respective values, are shown using standard industry nomenclature.

The terms and expressions which have been employed in the foregoing specification are used therein as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow.

What is claimed is:

1. In an induction balance transmit/receive type of portable metal detector having an oscillator, a search head with a transmit coil driven by said oscillator to produce a magnetic field and a receive coil producing as an output a loop return signal responsive to changes in said magnetic field caused by the nearby environment, a pair of phase detectors receiving said loop return signal and producing a pair of component signals in quadrature, means for adding said component signals together to produce a phase detection signal, and indicator means responsive to the amplitude of said phase detector signal, the improvement comprising:

(a) air balance circuit means, responsive to said phase detector signal when said search head is held away and remote from the ground, for automatically adjusting said phase detection signal level so as to cancel out offsets occurring in said loop return signal;

(b) static ground balance circuit means for screening out on a one-time, user-actuatable basis ground effects, said ground effects being the effects on said loop return signal of the mineralization content of the ground in the vicinity of said metal detector;

(c) dynamic ground balance circuit means for screening out on a continuing, repetitive basis said ground effects; and

(d) user-selectable switch means for transferring said metal detector being two modes of operation, the first mode utilizing said air balance circuit means to adjust said phase detection signal to an air balance level of said detector, and the second mode utilizing said static and said dynamic ground balance circuit means to provide a screening out from said phase detection signal of said ground effects.

2. The metal detector of claim **1** including control means for varying the sensitivity of said detector in responding to the mineralization content of the ground in the vicinity of said detector.

3. The metal detector of claim **1** including means for providing an indication when said air balance circuit means has completed said adjustment.

4. The metal detector of claim **1** wherein said dynamic ground balance circuit means has a circuit time constant which is at least an order of magnitude larger than the circuit time constant of said static ground balance circuit means so as to slow the response and thereby avoid hunting in the operation of said dynamic ground balance circuit means.

5. The metal detector of claim **1** wherein a first indication is given when said metal detector has completed

an air balance operation and a second indication is given when said metal detector has completed a static ground balance operation.

6. The metal detector of claim 1 characterized in that said dynamic ground balance circuit means includes slope detector means for producing an output signal responsive to both a change in the distance of said search head from the ground and the direction of said change, said output signal being utilized in said dynamic ground balance circuit means for screening out said ground effects.

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